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RESEARCH MEMORANDUM

CONTROL CHARACTERISTICS AT TRANSONIC SPEEDS OF

A LINKED FLAP AND SPOILER ON A TAPERED

45° SWEPTBACK WING OF ASPECT RATIO 3

By Vernard E. Lockwood and Joseph E. Fikes

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RESEARCH MEMORANDUM

CONTROL CHARACTERISTICS AT TRANSONIC SPEEDS OF

A LINKED FLAP AND SPOILER ON A TAPERED

45° SWEEPBACK WING OF ASPECT RATIO 3

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SUMMARY

An investigation has been made at transonic speeds to determine the control characteristics of a linked flap and spoiler. The control consisted of a linked combination of a quarter-span inboard plug-type spoiler and a full-span flap. The control was mounted on a 7.6-percent-thick 45° sweptback wing of aspect ratio 3 and taper ratio 0.5. The investigation was made in the Langley high-speed 7- by 10-foot tunnel. Transonic speeds were obtained by testing in the high-velocity flow field over a reflection plane on the side wall of the tunnel. A comparison of the results of this investigation with those of a previous investigation of a plain flap (NACA RM L51L19) indicated that considerable balancing effect was obtained on the flap hinge moments when the spoiler and flap were deflected together over the entire range of angles of attack and Mach numbers. The control also gave increments in lift and roll greater than that of the plain flap at 0° and 4° angles of attack; but, at angles of attack greater than 8°, the combination gave less lift and roll effectiveness than the plain flap.

INTRODUCTION

At the present time the NACA is investigating various types of aerodynamically balanced control surfaces in the transonic speed range. Balancing devices such as overhangs, horns, tabs, auxiliary lifting surfaces, and combinations thereof are being considered. Some preliminary investigations have been made on some of these controls, the results of which are presented in references 1 to 4. In all these investigations, as in the present case, no attempt is being made to obtain design information, that is, to determine the exact amount of balance required to balance the surface completely. The emphasis is

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being placed, however, on finding whether the control device or combinations thereof appear promising at transonic speeds. One such combination which has shown the balancing effect on flaps of unswept wings to be promising at subsonic speeds was a spoiler located ahead of the flap and deflected in the same direction as the flap (refs. 5 and 6).

The control arrangement of the present investigation consisted of a quarter-span inboard plug-type spoiler linked to a full-span flap such that the spoiler deflected in the same direction as the flap and in the ratio of approximately 0.4-percent-chord spoiler projection to 1° flap deflection. The investigation was made on a tapered 45° sweptback wing of aspect ratio 3. The hinge moments measured were those of the flap-spoiler combinations. The lift, drag, pitching-moment, rolling-moment and yawing-moment characteristics were also included. The results are presented for a limited angle-of-attack and flap-deflection range for a Mach number range of 0.70 to 1.10. The Reynolds number of the investigation was approximately 1×10^6 .

COEFFICIENTS AND SYMBOLS

C_L	lift coefficient, $\frac{\text{Twice semispan lift}}{qS}$
C_D	drag coefficient, $\frac{\text{Twice semispan drag}}{qS}$
ΔC_D	increment of drag coefficient caused by deflection of spoiler and flap
C_m	pitching-moment coefficient referred to $0.25\bar{c}$, $\frac{\text{Twice semispan pitching moment}}{qS\bar{c}}$
C_l	rolling-moment coefficient about axis parallel to relative wind and in plane of symmetry, $\frac{\text{Rolling moment of semispan model}}{qSb}$
C_h	flap hinge-moment coefficient, $\frac{\text{Flap hinge moment about hinge line of semispan flap}}{q_2 M^2}$

C_n	yawing-moment coefficient about axis through balance center perpendicular to relative wind and in plane of symmetry, <u>Yawing moment of semispan model</u> qSb
S	twice wing area of semispan model, 0.202 sq ft
b	twice semispan of model, 0.778 ft
\bar{c}	mean aerodynamic chord of wing, $\frac{2}{S} \int_0^{b/2} c^2 dy$, 0.269 ft
M'	area moment of semispan flap rearward of the hinge line about the hinge line, 0.000692 ft ³
q	effective dynamic pressure over span of model, $\frac{1}{2}\rho V^2$, lb/sq ft
c	local wing chord, ft
y	spanwise distance from plane of symmetry
ρ	mass density of air, slugs/cu ft
V	free-stream velocity, fps
M	effective Mach number over span of model, $\frac{2}{S} \int_0^{b/2} cM_a dy$
M_a	average chordwise local Mach number
M_l	local Mach number
R	Reynolds number of wing based on \bar{c}
α	angle of attack, deg
δ_f	flap deflection relative to wing-chord plane, measured in a plane perpendicular to flap hinge axis, deg; positive when trailing edge is down
δ_s	spoiler projection relative to wing surface, measured in a plane parallel to plane of symmetry, percent of local chord; positive when projected below lower surface of wing

Parameters:

$$C_{h\alpha} = \left(\frac{\partial C_h}{\partial \alpha} \right)_{\delta_f, \delta_s}$$

$$C_{h\delta_f} = \left(\frac{\partial C_h}{\partial \delta_f} \right)_{\alpha}$$

$$C_{l\delta_f} = \left(\frac{\partial C_l}{\partial \delta_f} \right)_{\alpha}$$

$$C_{m\delta_f} = \left(\frac{\partial C_m}{\partial \delta_f} \right)_{\alpha}$$

$$C_{l\delta_f} = \left(\frac{\partial C_l}{\partial \delta_f} \right)_{\alpha}$$

The subscripts outside parentheses indicate the factors held constant during the measurement of the parameters. The control parameters were determined from the increment in coefficients between 0° and 10° flap deflection.

MODEL AND APPARATUS

The steel semispan model used in the investigation had a quarter-chord sweep angle of 45.58°, an aspect ratio of 3, a taper ratio of 0.5, and was approximately 7.6 percent thick. The airfoil section was an NACA 64A010 which was measured in a plane at 45° to the plane of symmetry. The pertinent dimensions of the basic wing are given in figure 1 and a photograph of a typical wing mounted on the reflection plane is shown in figure 2. The wing was equipped with a full-span plain flap-type control of 25.4 percent of the chord measured parallel to the plane of symmetry. The wing was also equipped with an inboard quarter-span plug-type spoiler located just ahead of the flap as shown in figure 3. The spoiler was connected to the flap with a linkage designed to deflect the spoiler in the same direction as the flap in the ratio of approximately 0.4-percent-chord spoiler projection to 1° flap deflection. The variation of the spoiler projection (in percent chord) with flap deflection (in degrees) is shown in figure 4 for the condition of no load.

The investigation was conducted in the Langley high-speed 7- by 10-foot tunnel using a small reflection plane set up on the side wall

which induced local supersonic flow when the tunnel is near maximum velocity. The reflection plane was mounted a few inches from the side wall as shown in figure 1. The model was mounted through a turntable in the reflection plane and a gap of about 1/16 inch was maintained between the wing root chord section and the reflection-plane turntable. A sponge-wiper seal was fastened to the wing butt to minimize flow through the gap.

The model was mounted on an electrical strain-gage balance and the moments and forces were indicated by self-balancing potentiometers. The hinge moments of the flap-spoiler combination were indicated by a strain-gage beam attached to the flap shaft.

TESTS

The tests were made through an angle-of-attack range of 0° to 16° and through a flap-deflection range of ±10° with spoiler projections of approximately ±4 percent chord and over a Mach number range of 0.70 to 1.10. For Mach numbers below 0.95 there was practically no gradient in the vicinity of the reflection plane. At higher Mach numbers, the presence of the reflection plane created a high-local-velocity field which allowed the model to be tested up to a Mach number of 1.10 before choking occurred in the tunnel. Typical variations of local Mach numbers are shown in figure 5. The effective test Mach numbers were obtained from contour charts similar to those shown in figure 5 by the relationship

$$M = \frac{2}{S} \int_0^{b/2} cM_a dy$$

A typical variation of Reynolds number with Mach number through the transonic speed range is shown in figure 6.

CORRECTIONS

The aileron effectiveness parameters $C_{l\delta}$ presented herein represent the aerodynamic effects on a complete wing produced by the deflection of the control surface on only one semispan of the complete wing. A reflection-plane correction, which accounts for the carry over of

load to the other wing, has been applied to this parameter $C_{l\delta}$ throughout the Mach number range tested. The corrected value of $C_{l\delta}$ was obtained as follows:

$$C_{l\delta} = C_{l\delta_u} - KC_{l\delta_u}$$

where $C_{l\delta_u}$ is the uncorrected aileron effectiveness parameter and K is the correction factor (0.33). The correction factor was obtained from an unpublished experimental investigation at low speed ($M \approx 0$) and from theoretical considerations. Although the corrections are based on incompressible conditions, it is believed that the results obtained by applying the correction factor gives a better representation of the true conditions than the uncorrected results. Flap deflections were corrected for angle change due to strain-gage deflection under load.

No attempt has been made to apply corrections for jet-boundary or blockage effects. Because of the small size of the model, these corrections are believed to be small.

RESULTS AND DISCUSSION

Variation of the hinge-moment and other aerodynamic characteristics of the linked flap and spoiler with flap deflection are shown in figure 7 for various angles of attack and Mach numbers. The control effectiveness parameters are given in figure 8. The values of the hinge-moment parameter $C_{h\alpha}$ presented in figure 9 were determined from the increment in hinge-moment coefficient between 0° and 4° angle of attack at $\delta_f = 0^\circ$. The parameters of the plain flap taken from reference 4 were included in figures 8 and 9.

Hinge-moment characteristics.— The hinge-moment parameters $C_{h\delta_f}$, which are based on the increment of hinge-moment coefficient between 0° and 10° flap deflection, indicates considerable balancing effect of the spoiler on the flap (fig. 8) throughout the angle-of-attack and Mach number range tested. At low angles of attack the parameters present a conservative indication of the balancing effect of the spoiler because of the nonlinear variation of hinge-moment coefficient with flap deflection (fig. 7(a)).

The primary balancing effect of the spoiler probably results from the negative pressure created on the flap behind the spoiler. A small

secondary balancing effect of the spoiler in the low deflection range results from the hinge moments of the spoiler which are opposite in sign to those of the flap as shown in reference 7. Unpublished data indicate that additional balancing would result from increasing the span of the spoiler.

The variation of $C_{h\alpha}$ with Mach number (fig. 9) for the linked flap and spoiler is quite similar to that obtained from the plain flap of reference 4, but is more negative than the plain flap through most of the Mach range tested. These more negative values of $C_{h\alpha}$ are in agreement with the hinge moments of the spoiler alone shown in reference 7.

Pitching-moment characteristics.- The variation of pitching-moment coefficient with flap deflection (fig. 7(b)) is nearly linear in the flap-deflection range of $\pm 5^\circ$ for angles of attack of 0° through 8° . Some decrease in effectiveness is noted for most flap deflections greater than $\pm 5^\circ$ at low angles of attack and a considerable loss is noted between 5° and 10° flap deflection for 12° and 16° angle of attack. For this reason the indicated effectiveness $C_{m\delta_f}$ (fig. 8) measured between flap deflections of 0° and 10° is less than that which exists in the low-flap-deflection range. Only small changes in pitching effectiveness with Mach number are indicated for the range of angles of attack.

Lift characteristics.- The variations of lift coefficient with flap deflection (fig. 7(c)) are nonlinear for most of the conditions tested particularly at negative flap deflections and the high angles of attack ($\alpha = 12^\circ$ and 16°). The lift effectiveness parameter $C_{l\delta_f}$ (fig. 8) indicates that the flap-spoiler combination gave an increase in the lift effectiveness over the plain flap at the low angles of attack ($\alpha = 0^\circ$ and 4°) throughout the Mach range tested, but gave less effectiveness than the plain flap at the higher angles of attack ($\alpha = 12^\circ$ and 16°).

Rolling-moment characteristics.- The aileron effectiveness as indicated by $C_{l\delta_f}$ (fig. 8) varies with angle of attack and Mach number in a manner similar to that of the lift effectiveness; that is, the aileron effectiveness is greater for the linked flap and spoiler than the plain flap of reference 4 for angles of attack of 0° and 4° and is less for angles of attack of 12° and 16° .

CONCLUDING REMARKS

An investigation at transonic speeds of a 7.6-percent-thick 45° sweptback wing of aspect ratio 3 having a full-span flap linked to an

inboard quarter-span plug spoiler deflecting in the same direction as the flap indicated the following:

1. The linked control gave considerable balancing effect over that of the plain flap.

2. The lift and roll was increased over that of the plain flap at angles of attack of 0° and 4° through the Mach number range. At angles of attack greater than 8° the combination gave less lift and roll effectiveness than the plain flap.

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REFERENCES

1. Lockwood, Vernard E., and Hagerman, John R.: Aerodynamic Characteristics at Transonic Speeds of a Tapered 45° Sweptback Wing of Aspect Ratio 3 Having a Full-Span Flap Type of Control with Overhang Balance. Transonic-Bump Method. NACA RM L51L11, 1952.
2. Lowry, John G., and Fikes, Joseph E.: Preliminary Investigation of Control Characteristics at Transonic Speeds of a Tapered 45° Sweptback Wing of Aspect Ratio 3 Having a Horn-Balanced Full-Span Control. NACA RM L52A11, 1952.
3. Lockwood, Vernard E., and Fikes, Joseph E.: Preliminary Investigation at Transonic Speeds of the Effect of Balancing Tabs on the Hinge-Moment and Other Aerodynamic Characteristics of a Full-Span Flap on a Tapered 45° Sweptback Wing of Aspect Ratio 3. NACA RM L52A23, 1952.
4. Moseley, William C., Jr.: Preliminary Investigation of the Effects of a Paddle Balance on the Control Characteristics at Transonic Speeds of a Tapered 45.58° Sweptback Wing of Aspect Ratio 3 Having a Full-Span Flap-Type Control. NACA RM L51L19, 1952.
5. Laitone, Edmund V.: An Investigation of the High-Speed Lateral-Control Characteristics of a Spoiler. NACA ACR 4C23, 1944.
6. Laitone, Edmund V., and Summers, James L.: An Additional Investigation of the High-Speed Lateral-Control Characteristics of Spoilers. NACA ACR 5D28, 1945.
7. Fikes, Joseph E.: Hinge-Moment and Other Aerodynamic Characteristics at Transonic Speeds of a Quarter-Span Spoiler on a Tapered 45° Sweptback Wing of Aspect Ratio 3. NACA RM L52A03, 1952.

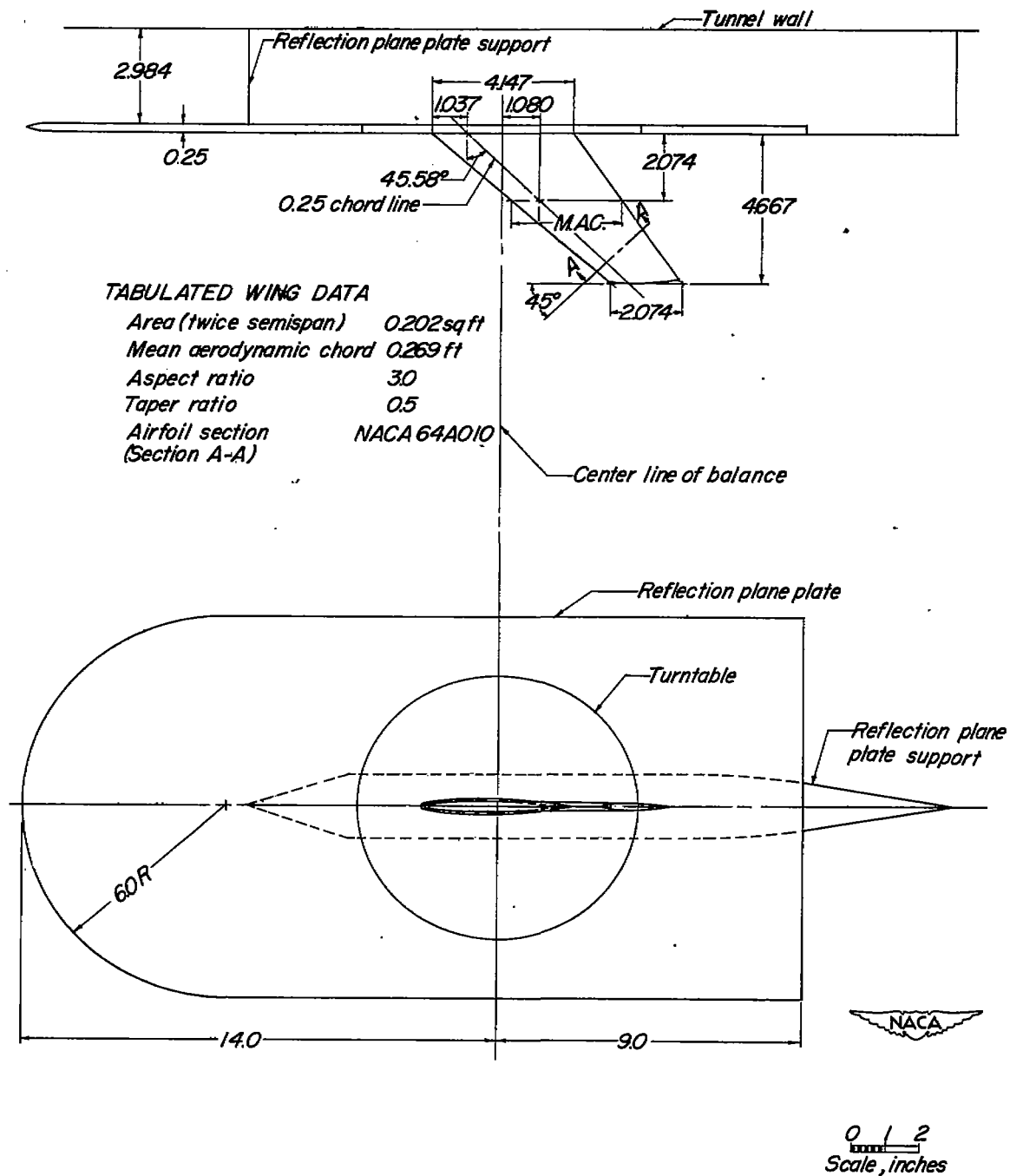


Figure 1.- Basic wing model mounted on the reflection plane in the Langley high-speed 7- by 10-foot tunnel.

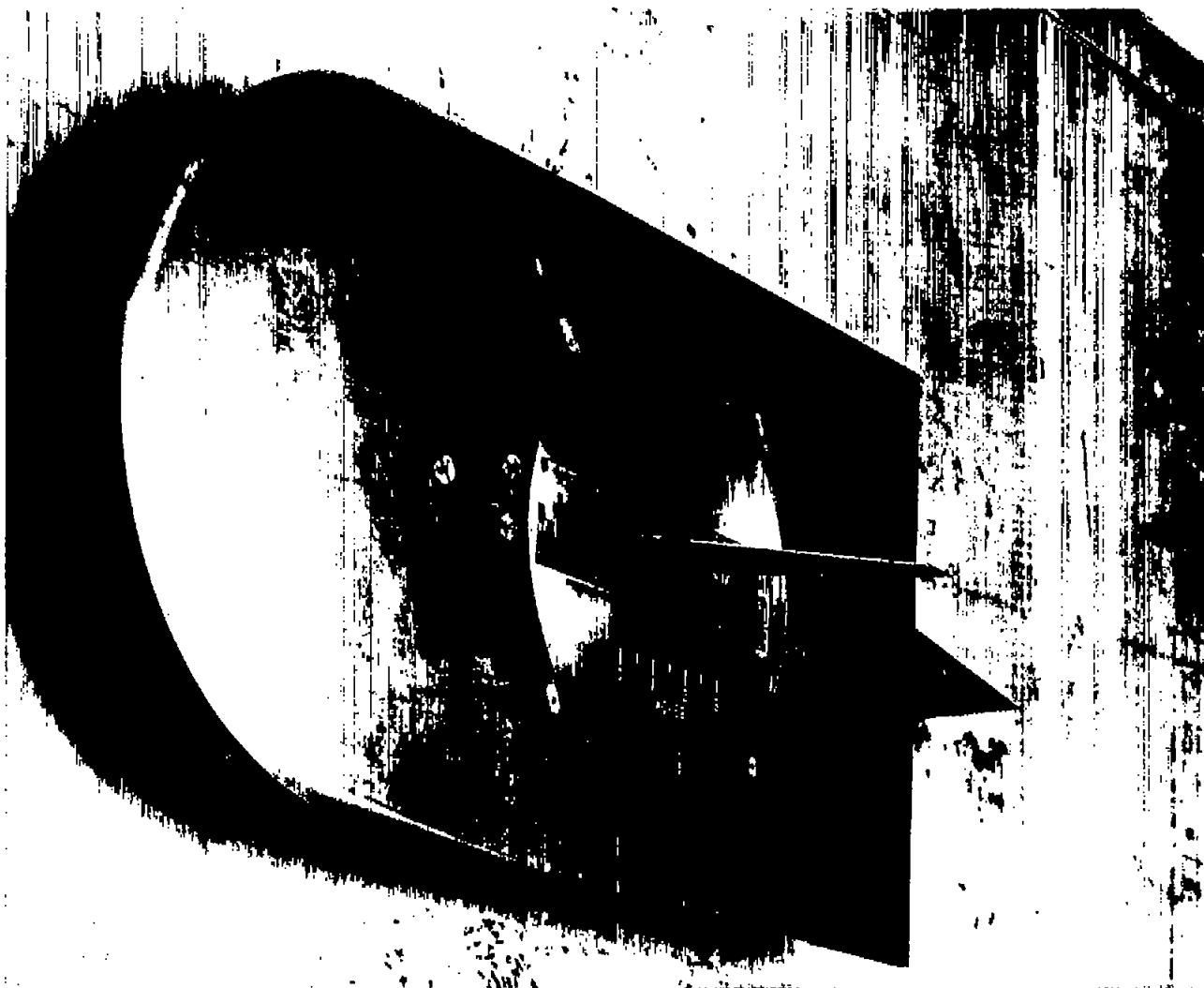


Figure 2.- View of typical model mounted on the reflection plane in the Langley high-speed 7- by 10-foot tunnel.

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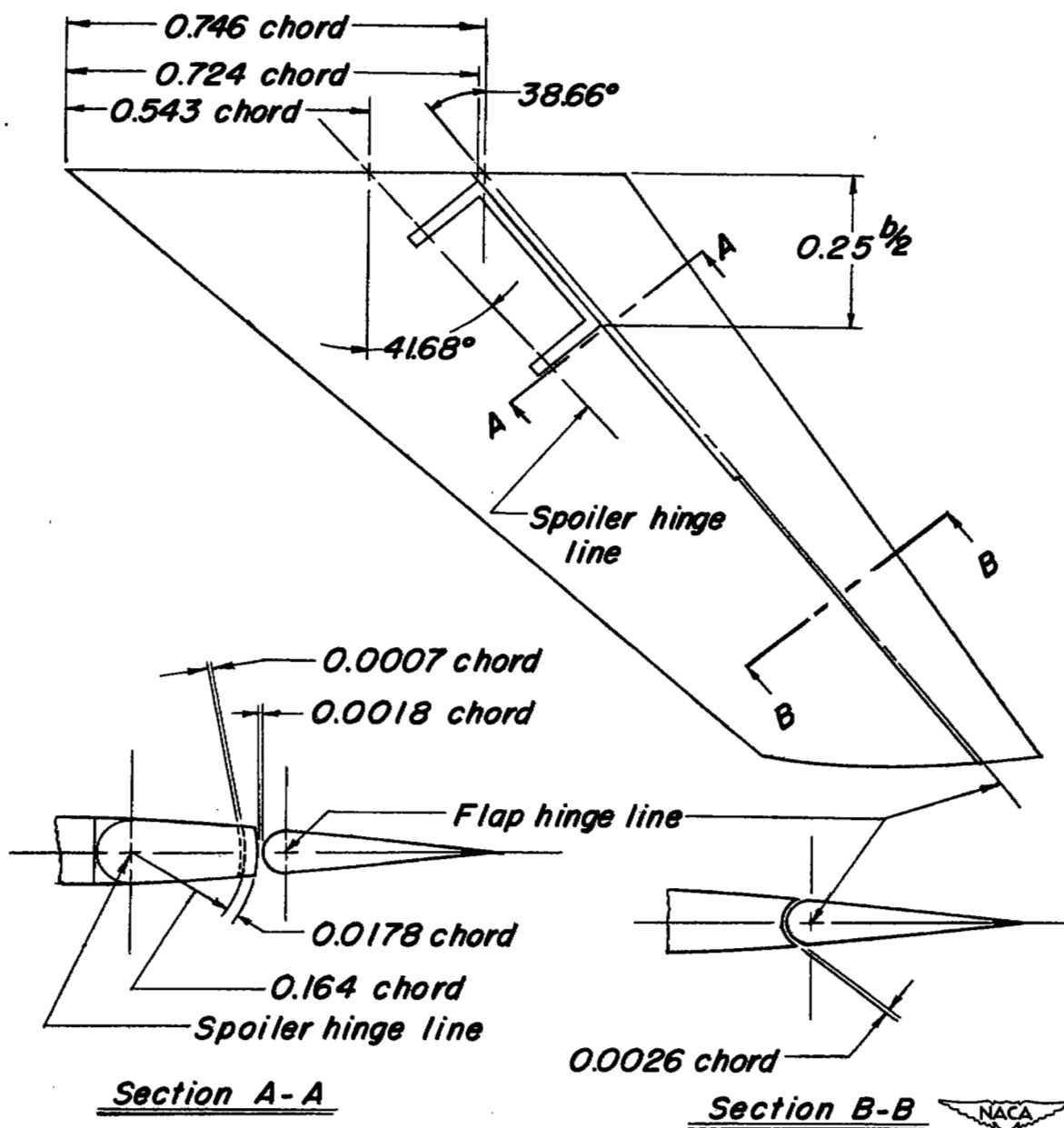


Figure 3.- Details of control tested.

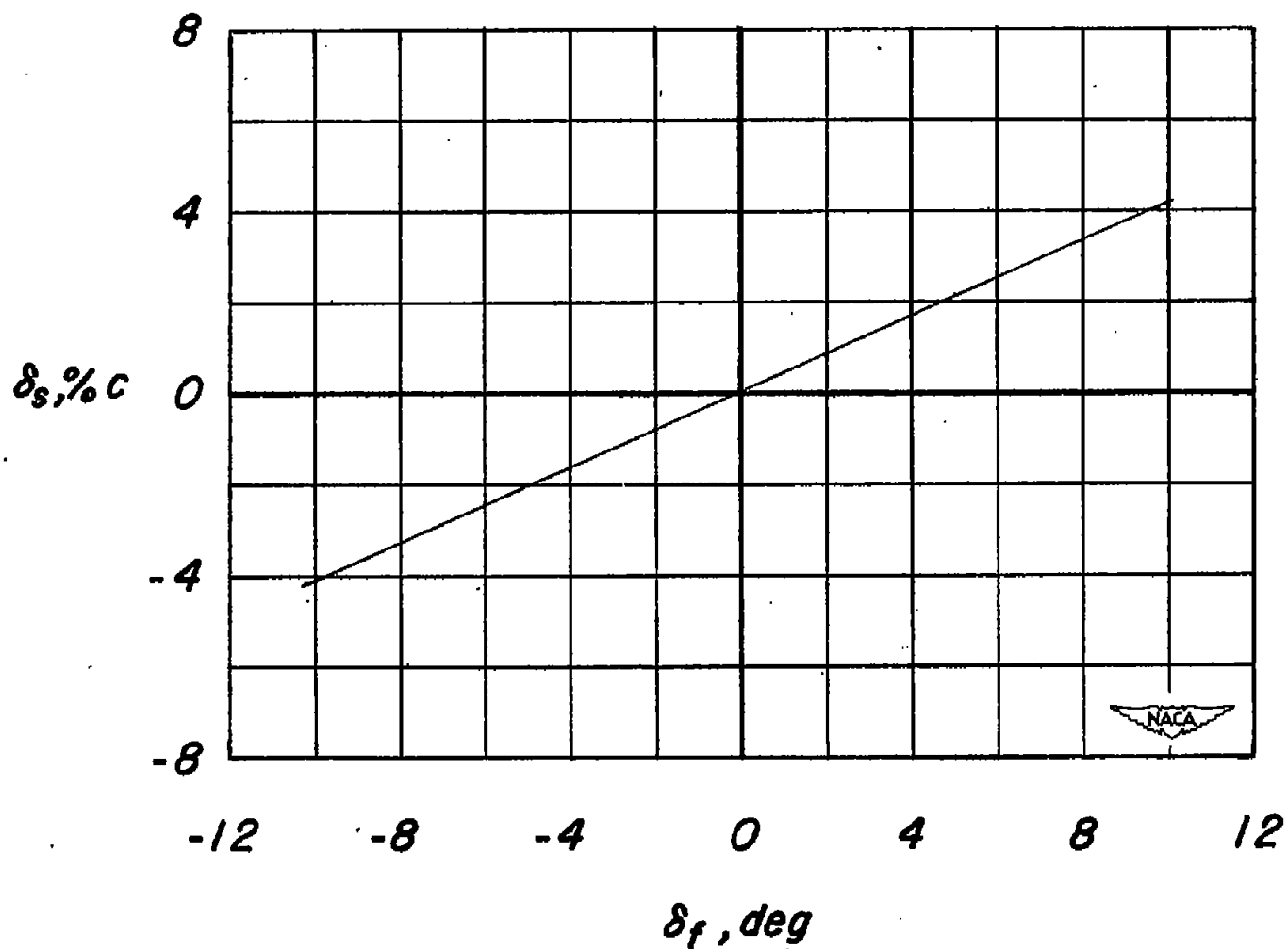
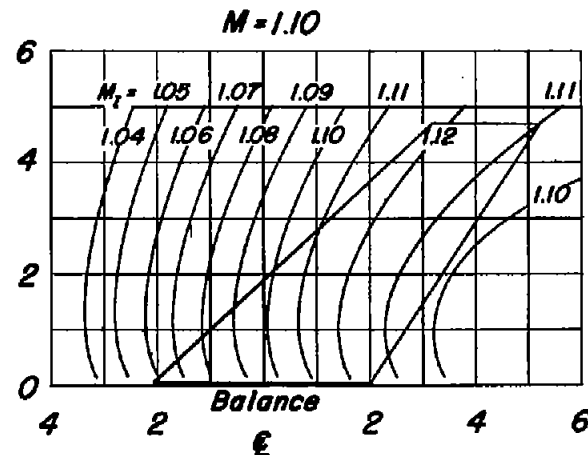
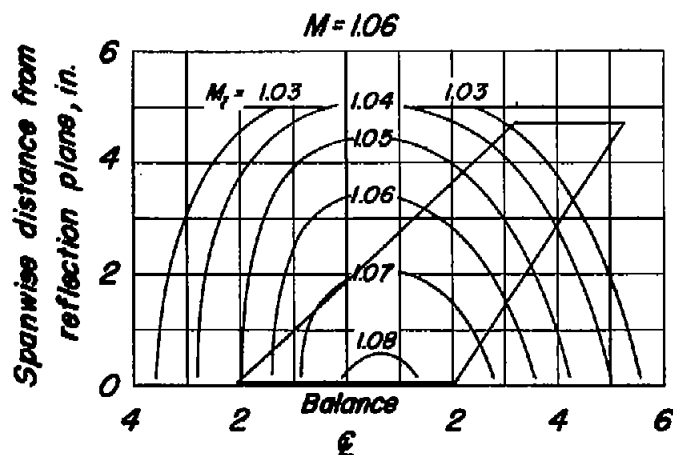
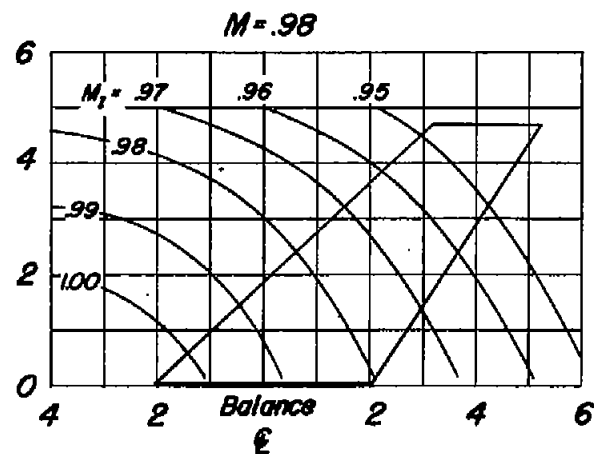
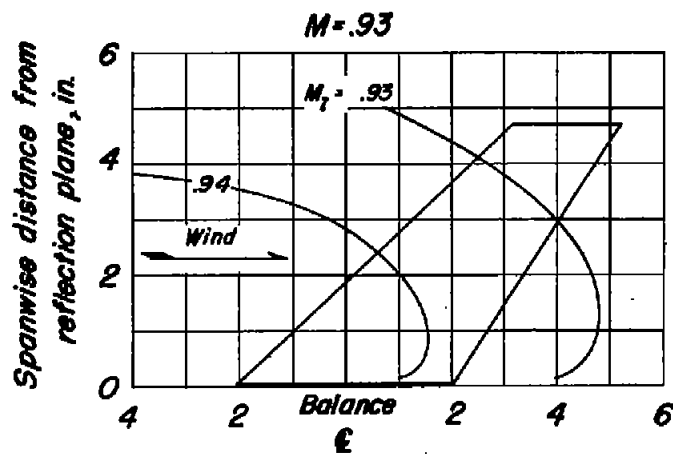


Figure 4.- Variation of spoiler projection with flap deflection.



Longitudinal distance along reflection plane, in.

Longitudinal distance along reflection plane, in.

Figure 5.- Typical Mach number contours over the side-wall reflection plane in region of model location.

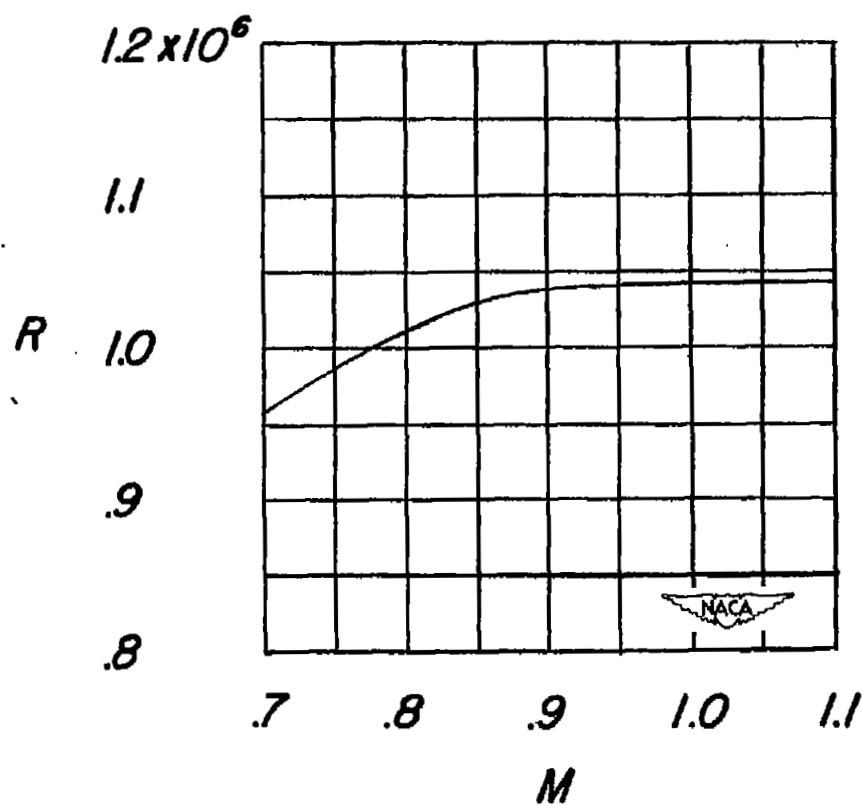
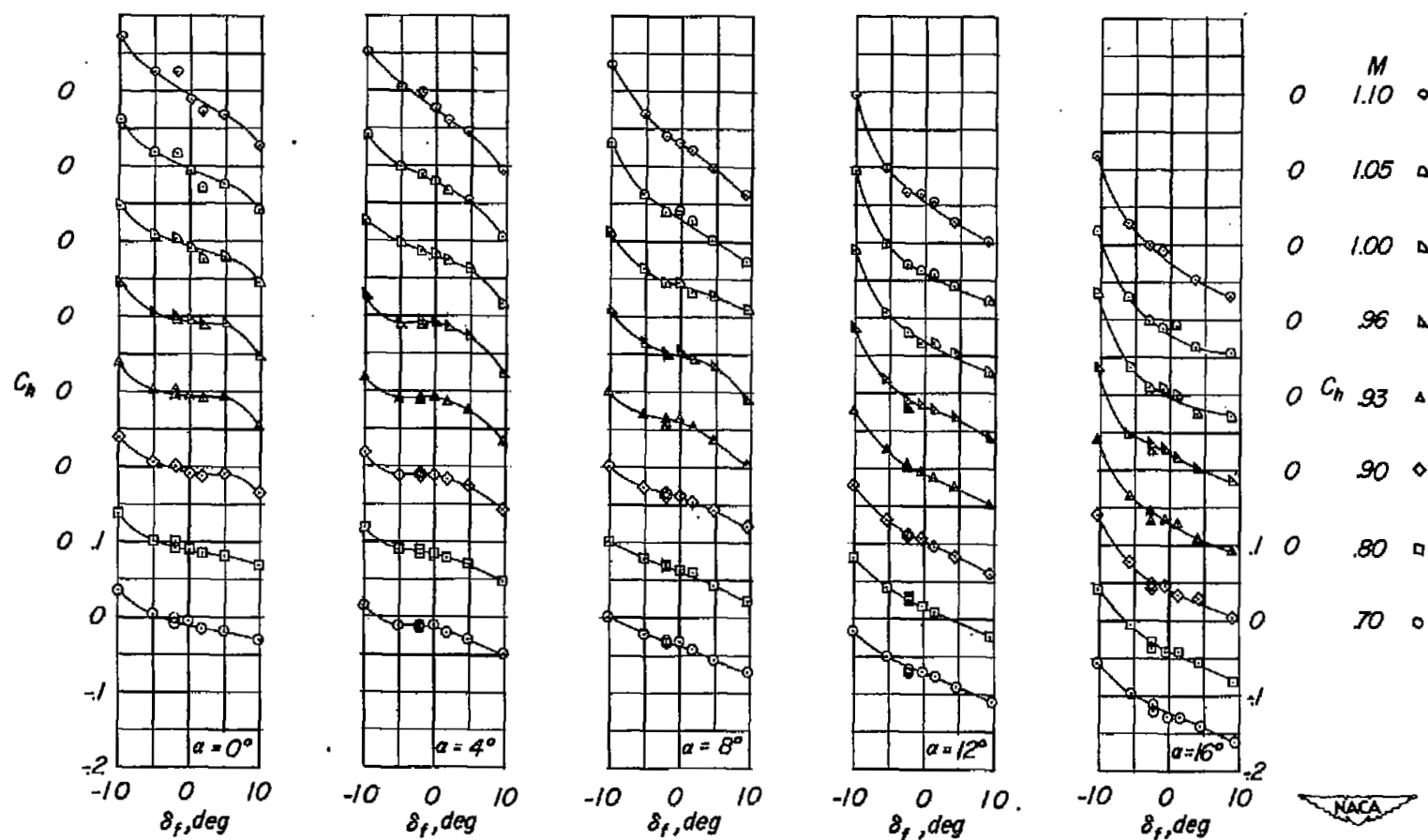


Figure 6.- Typical variation of Reynolds number with test Mach number through the transonic speed range.



(a) C_L against δ_f .

Figure 7.- Variation of aerodynamic characteristics with flap deflection for various Mach numbers and angles of attack.

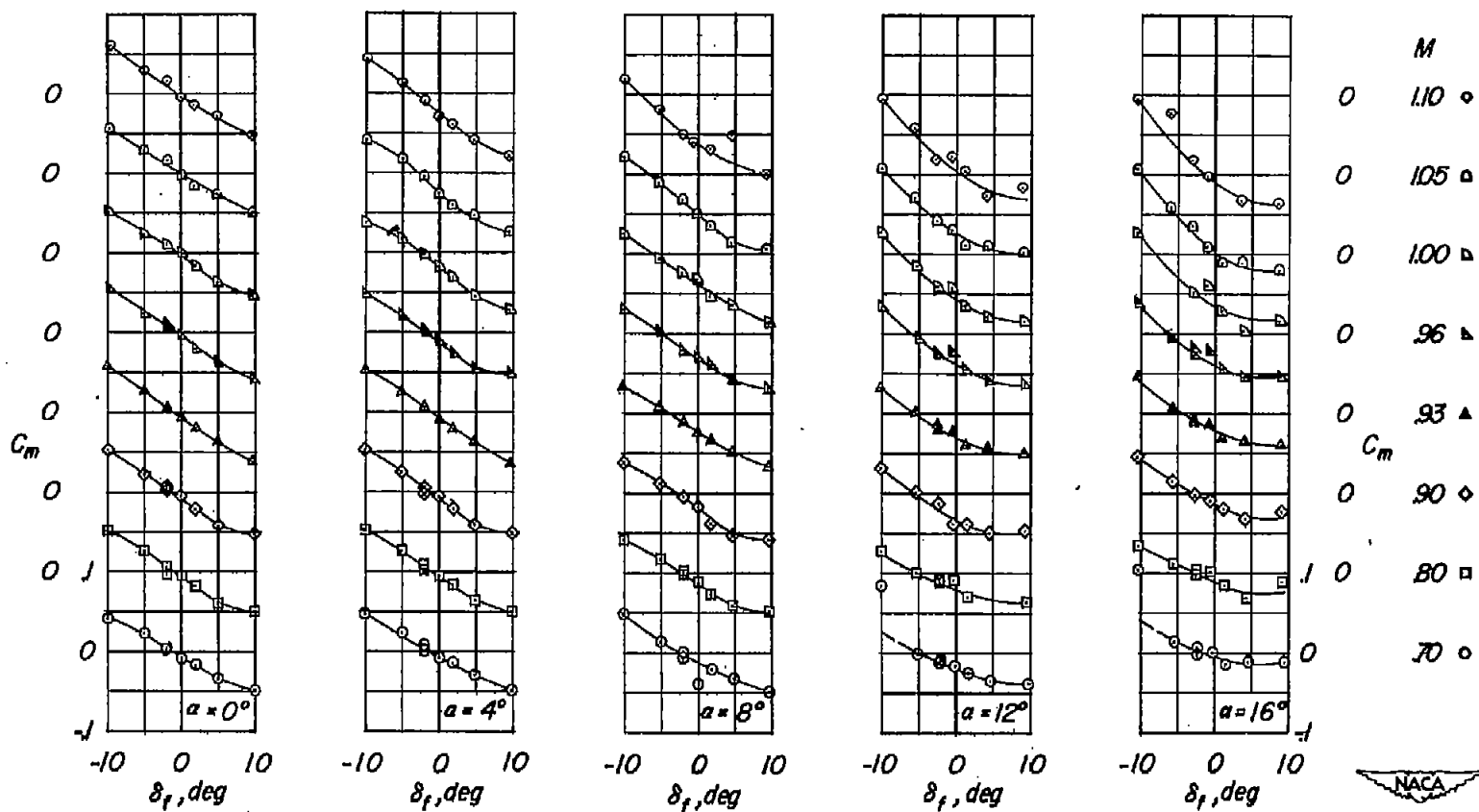
(b) C_m against δ_f .

Figure 7.- Continued.

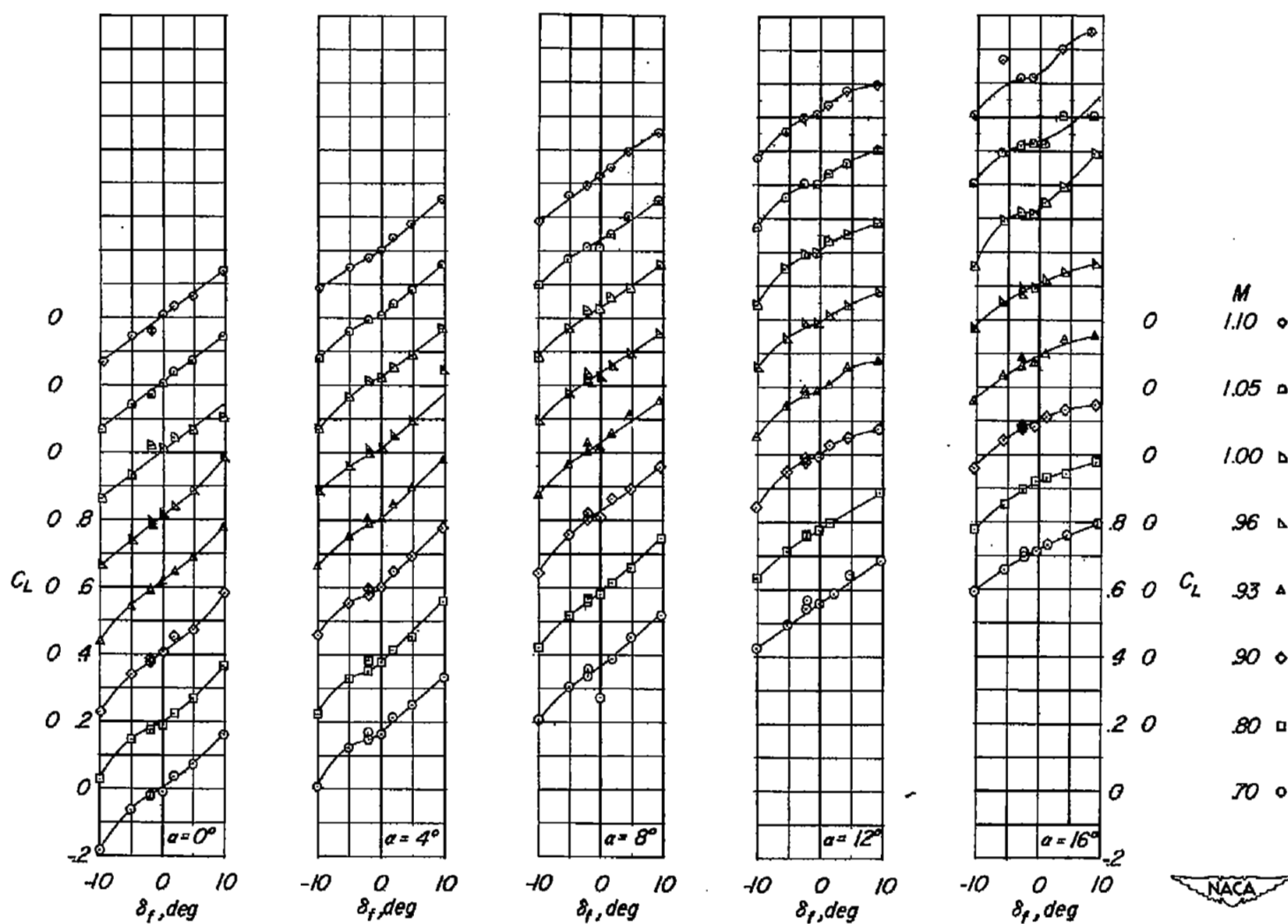
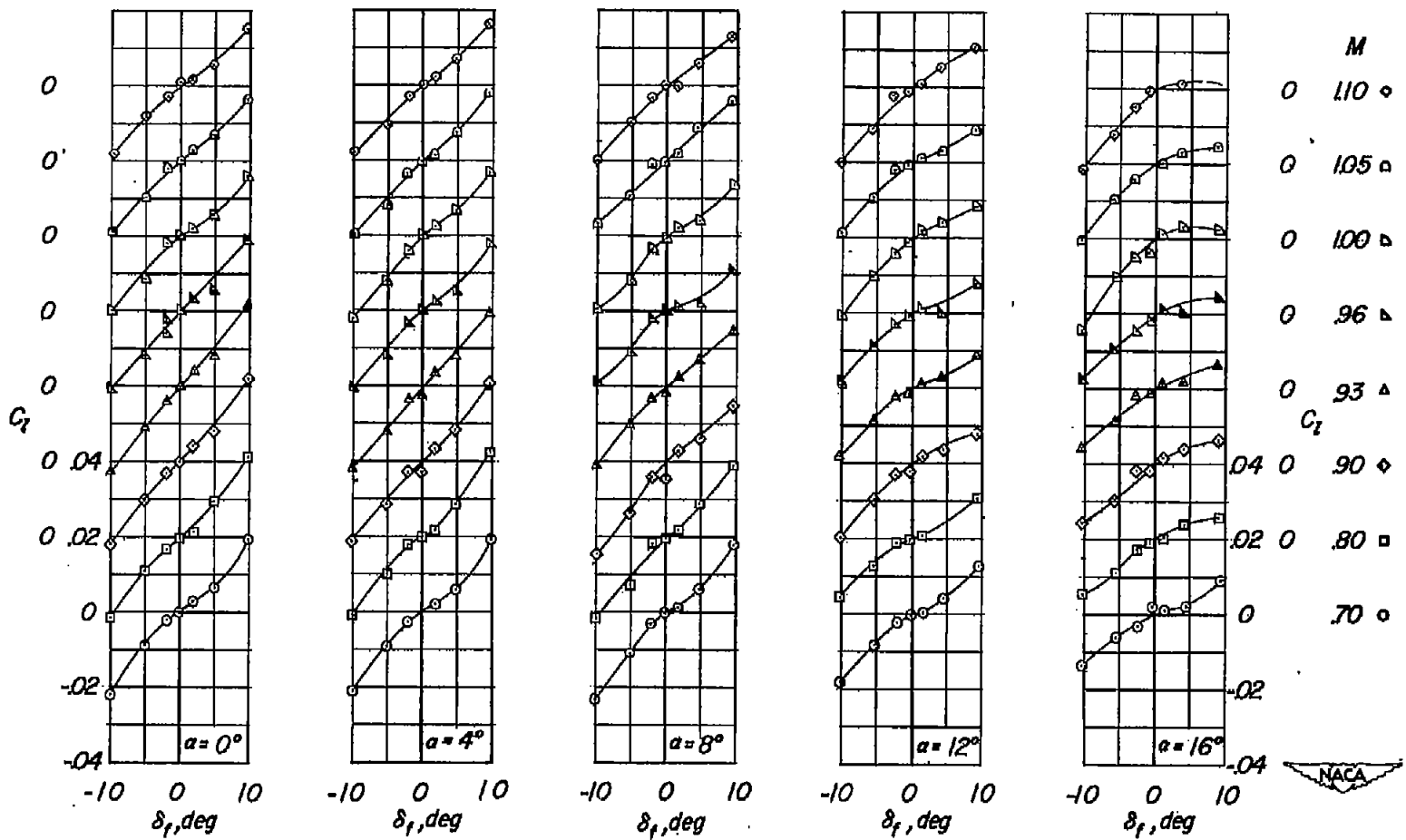
(c) C_L against δ_f .

Figure 7.- Continued.



(d) C_L against δ_f .

Figure 7.- Continued.

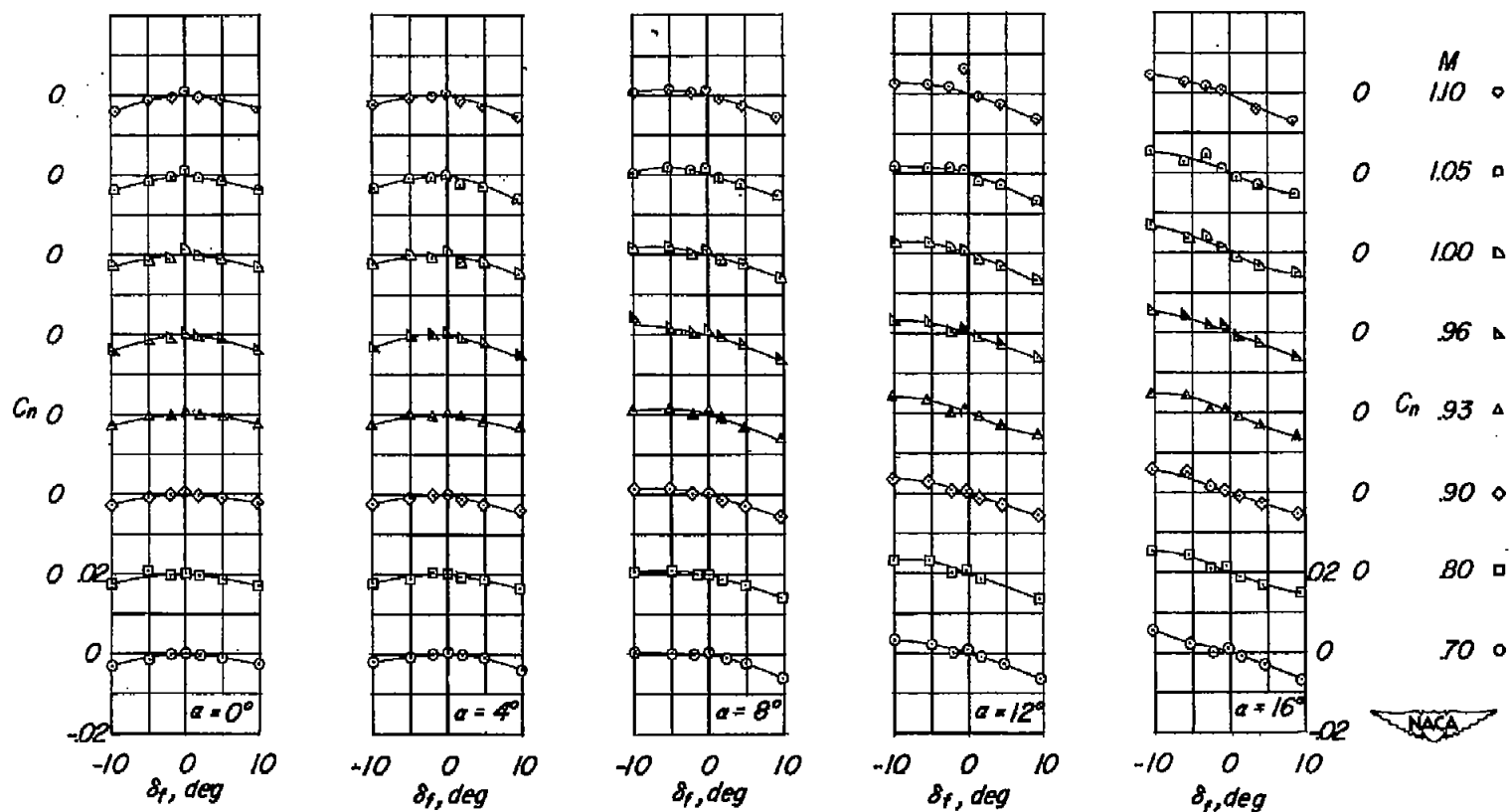
(e) C_n against δ_f .

Figure 7.- Continued.

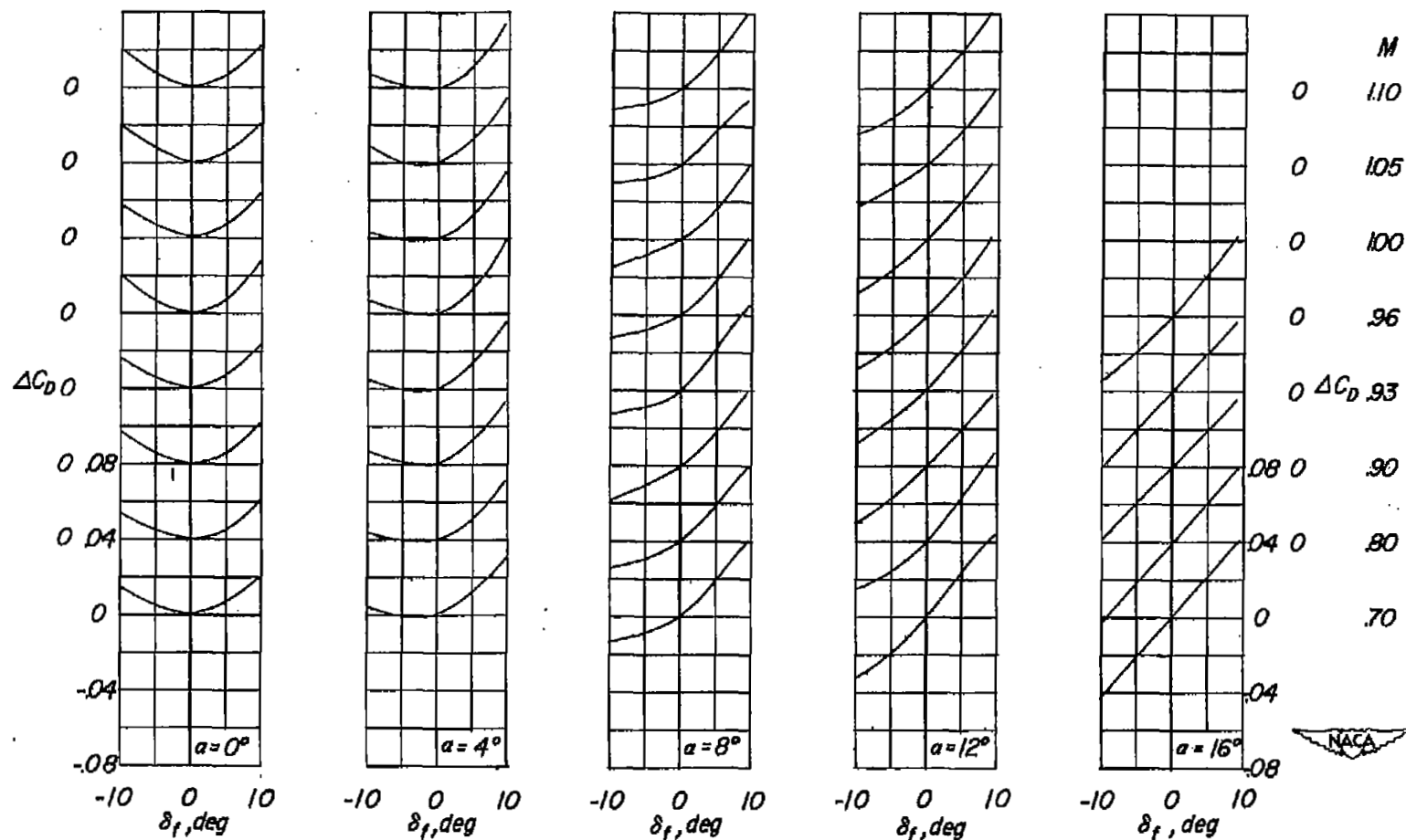
(f) ΔC_D against δ_f .

Figure 7.- Concluded.

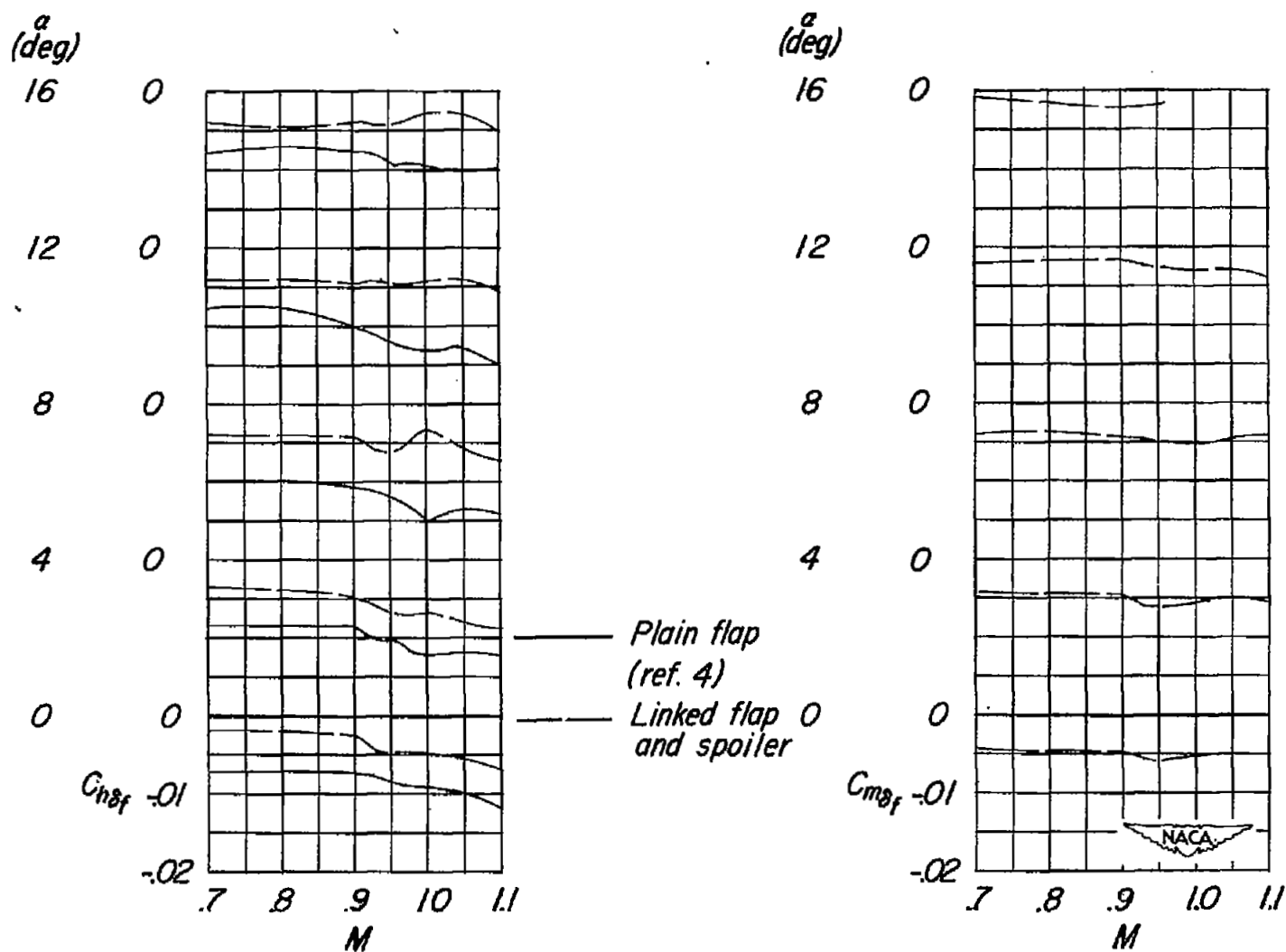
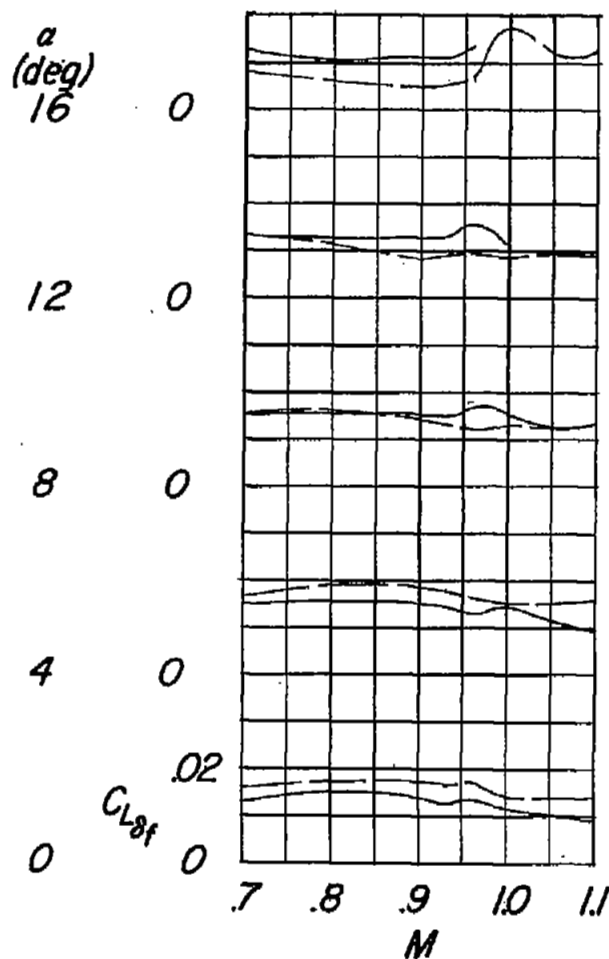


Figure 8.- Variation of the control effectiveness parameters with Mach number for various angles of attack.



— Plain flap
(ref. 4)
- - - Linked flap 4
and spoiler

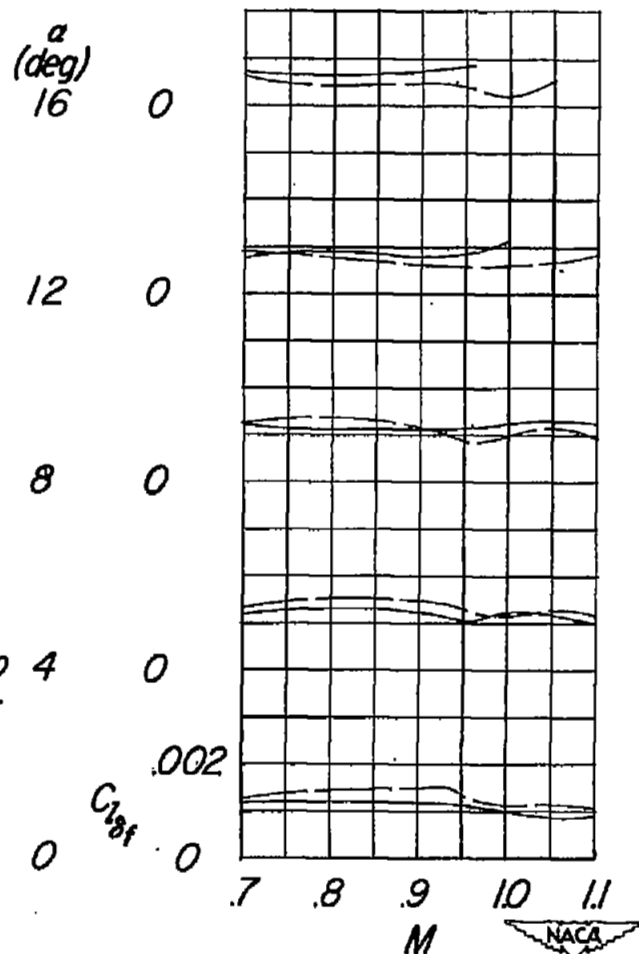


Figure 8.- Concluded.

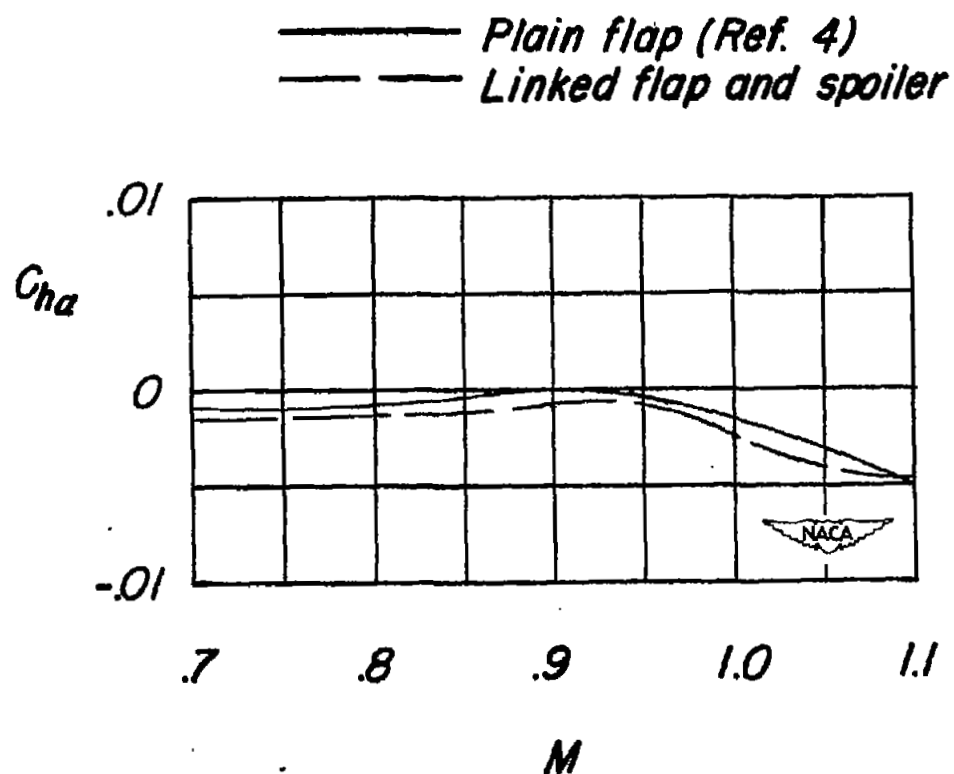


Figure 9.- Variation of hinge-moment parameter $C_{h\alpha}$ with Mach number M .

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